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Technical Report 32-1423

Addition of a Gamma Ray Spectrometer to the Alpha Scattering Experiment as Designed for the Surveyor Mission

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Prepared Under Contract No. NAS 7-100
National Aeronautics and Space Administration

Preface

The work described in this report was performed by the Space Sciences Division of the Jet Propulsion Laboratory, and by the Analog Technology Corporation, Pasadena, California.

Acknowledgment

It is a pleasure to express our appreciation for the cooperation of Dr. Anthony L. Turkevich of the University of Chicago, and Mr. Ernest J. Franzgrote of the Jet Propulsion Laboratory, in making the *Surveyor* P-1 alpha scattering instrument available for this study, and in giving helpful advice and information regarding its design and operation.

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Abstract

Gamma ray spectroscopy and alpha scattering are separate techniques that can be used for the compositional analysis of lunar and planetary surfaces. This report shows that it is possible to combine a gamma ray spectrometer with an alpha scattering instrument in a relatively simple manner, so that they can operate sequentially while sharing much of the electronics. The interfaces which have been designed and tested are based on the alpha scattering instrument that performed successfully in the *Surveyor* program.

Addition of a Gamma Ray Spectrometer to the Alpha Scattering Experiment as Designed for the *Surveyor* Mission

I. Introduction

In 1966 the payload of science instruments to be carried on the last three *Surveyor* missions was changed to conform to a reduction in payload capability. The prospect that *Surveyors V, VI,* and *VII* would carry the alpha scattering experiment together with a television package suggested the possibility of adding a gamma ray spectrometer to operate in conjunction with the alpha scattering instrument.* The alpha scattering instrument performs an analysis of a wide range of the more abundant elements (Ref. 1). A gamma ray spectrometer has the capability of providing additional geochemical information and of supplementing data from the alpha scattering experiment. The studies to be discussed were undertaken to show that the engineering requirements for an additional gamma ray capability could be made remarkably simple, since many of the required components are common to both instruments and were therefore already present in the alpha scattering instrument. The advanced state of the *Surveyor* program in 1966 as well as the limitations in weight capability prevented any implementation of these studies at that time.

*The actual flight configuration of *Surveyors V, VI,* and *VII* included, besides the alpha scattering and TV experiments, a pair of magnets for determining the quantity of free iron on the lunar surface. *Surveyor VII* also carried the surface sampler experiment, which had been part of the *Surveyor III* payload.

More recently the conclusions of the Santa Cruz study regarding future lunar science exploration included both an alpha scattering spectrometer and a gamma ray spectrometer in a list of recommended instruments (Ref. 2). In this report, a design approach is described that combines both experiments into one instrument. Although the approach is not to be considered fixed, it does demonstrate the easy compatibility and overall economies possible wherever the mission sequence is suitable for both experiments.

This study was undertaken with the possibility of a *Surveyor* application. Therefore, the following guidelines were adopted:

(1) Minimal changes to the spacecraft electrical and mechanical interfaces.

(2) No interference with the operational sequence of the alpha scattering experiment.

(3) Minimal changes to the existing alpha scattering instrument.

(4) Minimal new development to satisfy schedule and budgetary constraints.

(5) Adequate performance for the intended use.

The interfaces as designed met these requirements. Spacecraft changes were limited to (1) mounting the gamma ray spectrometer, (2) providing T-access to the existing alpha scattering detector head–digital electronics cabling, and (3) adding two conductors from the alpha scattering instrument to the gamma ray system.

II. Instrumental Method

The principles and performance characteristics of the alpha scattering instrument have been described in detail (Ref. 3). Briefly, alpha particles from the decay of curium 242 are elastically scattered by nuclei of the sample under analysis. The energy of an alpha particle after it has been scattered through a given angle characterizes the mass of the scattering nucleus. This energy is determined with a set of solid state detectors. Other solid state detectors provide additional information by responding to protons produced in α-p reactions. The energy of each detected alpha particle and proton is determined by pulse height analysis. The sensitivity of the technique for a given element ranges from 0.1 to 1% and improves with atomic number, while the resolving capability decreases with atomic number and prevents the unique analysis of adjacent elements above about $Z = 19$. The sampling depth is limited to a fraction of a millimeter by the limited range of the alpha particles. The alpha scattering experiment performed successfully on *Surveyors V, VI,* and *VII* (Ref. 4).

Gamma rays from the moon arise from two distinct mechanisms. Isotopes with half-lives long enough to be comparable to the time since nucleosynthesis ($\sim 10^9$ yr and over) will still be undergoing decay, generally with the emission of one or more characteristic gamma rays. The intensity of radiation will depend directly on the abundance of these radioactive elements in the lunar surface material. In the second mechanism, gamma rays are produced by the interaction between high energy charged particles of the cosmic ray or solar flux, and the lunar surface. Both a continuum and a complex line spectrum result.

Gamma rays can be detected efficiently by means of an inorganic crystal of thallium-activated sodium iodide [NaI(Tl)]. The energy of the gamma rays traversing the scintillation crystal is dissipated by various ionizing processes and subsequently transformed into light. This light is reflected and transmitted into a photomultiplier tube coupled to the scintillator. The output of the photomultiplier tube is an electrical pulse that is amplified and shaped, and then converted to a digital number proportional to the pulse amplitude. The digital number, representing the energy deposited by a single event in the scintillator, will be directed to telemetry and transmitted in real time.

Isotopes of potassium, thorium, and uranium generate thermal energy by the process of radioactive decay. If, taken together with other possible sources of energy, their concentrations have been sufficient to produce extensive melting then these elements along with others will be differentiated. Differentiation will increase the concentration of radioactive elements toward the surface as these form mineral phases of relatively lower density. Acidic rocks typical of the earth's crust possess abundances of potassium, thorium, and uranium up to two orders of magnitude greater than their undifferentiated counterparts. Under favorable conditions of counting time and detector resolution, a limited number of particle-induced characteristic gamma ray lines should be observable. The range of the gamma rays to be monitored is measured in centimeters so that a response can be obtained from an effective depth of several tens of grams per square centimeter.

An *in situ* gamma ray measurement does not have the information potential that an orbiting experiment promises in terms of total data return from a large fraction of the moon's surface. (A gamma ray spectrometer was carried on the *Luna X* orbiting spacecraft [Ref.5]). However, there is some compensation in the fact that several hours on the surface would provide optimum counting statistics for a single sample. A *Surveyor* type of measurement or its equivalent would also provide a point of ground verification for an eventual orbiter experiment. Figure 1 shows a synthesized lunar spectrum based on background data obtained in space by the *Ranger* gamma ray spectrometer, from a spectrum of induced activity derived from the exposure of a large mass of dunite to the cosmic ray flux at balloon altitudes, and from a 20-min measurement of the natural radioactivity of a rock with a potassium concentration of 0.14%. Potassium and thorium peaks at 1.46 MeV and 2.62 MeV, respectively, are only just visible above the continuum. Although the scintillation detector considered here is smaller and therefore has a lower efficiency, this will be offset by the long counting time available. Placing the detector several feet from a spacecraft with the mass of *Surveyor* should make it possible to detect potassium concentrations at the level of chondritic meteorites, i.e., 0.08%, a factor of 30 below the potassium content of some granites and rhyolites found on the earth.

Since the alpha scattering instrument cannot readily resolve elements with adjacent atomic numbers of $Z = 19$

and greater, only a composite analysis can be obtained for potassium and calcium, both of which are elements of major geochemical importance. If supporting evidence suggests that the moon is reasonably homogeneous to a depth of 1 to 20 g/cm^2 at the point of landing, then the measurement of potassium by the gamma ray spectrometer will allow the alpha scattering instrument to determine the calcium concentration by difference. Since the gamma ray spectrometer samples a much greater effective depth than the alpha scattering spectrometer, the determination of any major element by both techniques would provide evidence on the uniformity of composition over the micron-to-centimeter range of depth.

Installation of a gamma ray spectrometer on the minimal noninterference basis studied here would preclude an inflight measurement of the celestial flux and spacecraft background in cislunar space. Although this disadvantage would make calculations of the net lunar flux more difficult, an acceptable approximation can be obtained from accelerator experiments, balloon flights, and cislunar data of the *Ranger* gamma ray experiment.

III. Breadboard Design and Test Results

A breadboard, typical of a prototype instrument, was assembled for a limited test program. The approach to performing a lunar gamma ray analysis on a *Surveyor* spacecraft conceived of using the command, readout, and interface signal conditioning of the existing alpha scattering experiment system in conjunction with an auxiliary gamma ray assembly. The auxiliary assembly would contain the gamma ray detector, amplifier and height-to-time converter, anticoincidence system, interface logic and buffering, and power supplies. The existing digital electronics assembly of the alpha scattering instrument would provide the gated clock, telemetry readout, and command-memory system.

Changes to the alpha scattering instrument constituted the addition of a jumper wire to provide 29 Vdc for power and a second wire for receiving the gamma ray spectrometer output signal. This signal can be buffered with a single-transistor gate to be added at the input to the digital electronics. No other modifications to the alpha scattering instrument are required. No modifications to the detector head are required. Redundant protection against interference with the alpha scattering experiment is provided in the proposed design. First, the gamma ray spectrometer would be enabled only when the alpha scattering command calibration circuit and detectors are turned off in a specified sequence. Second, the added transistor gate within the alpha scattering digital electronics would only be enabled when the command-memory verification circuits (presently used for telemetry indication) verify that all alpha scattering detectors are in the *off* state. Signal and power interfaces would be protected by resistive isolation and by careful design of interface circuits to provide fail-safe operation. The gamma ray spectrometer would be operated only after completion of the alpha scattering experiment.

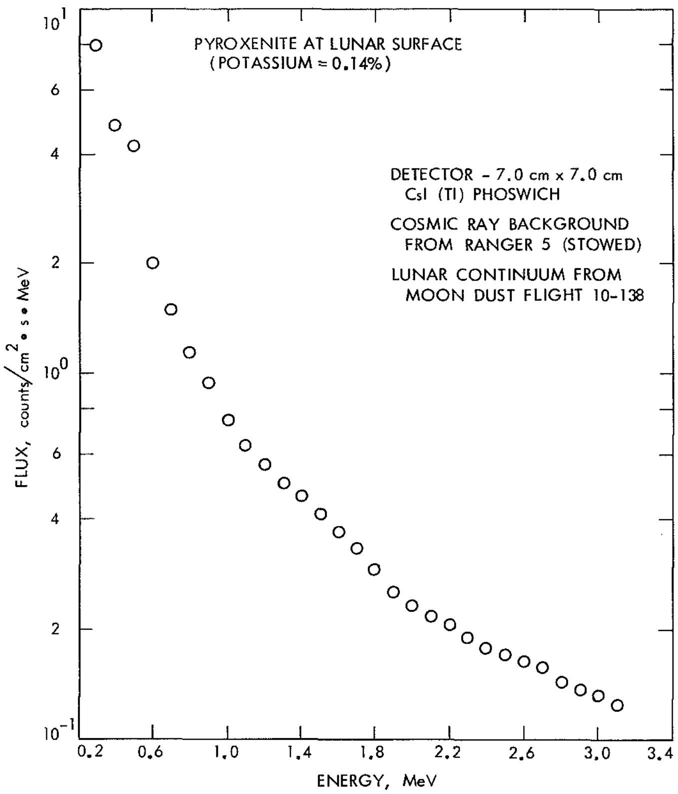

Fig. 1. Synthetic lunar spectrum

The tests to be described demonstrate that the proposed approach is feasible from an engineering standpoint and is capable of providing satisfactory experimental data. Much of the equipment used for the tests was nearly of flight quality.

A. Breadboard Configuration

The breadboard test configuration is shown in Fig. 2. The system consists of a 2 × 2-in. NaI(Tl) scintillator in a Harshaw integral line assembly connected to elements of the P-3A prototype second generation alpha

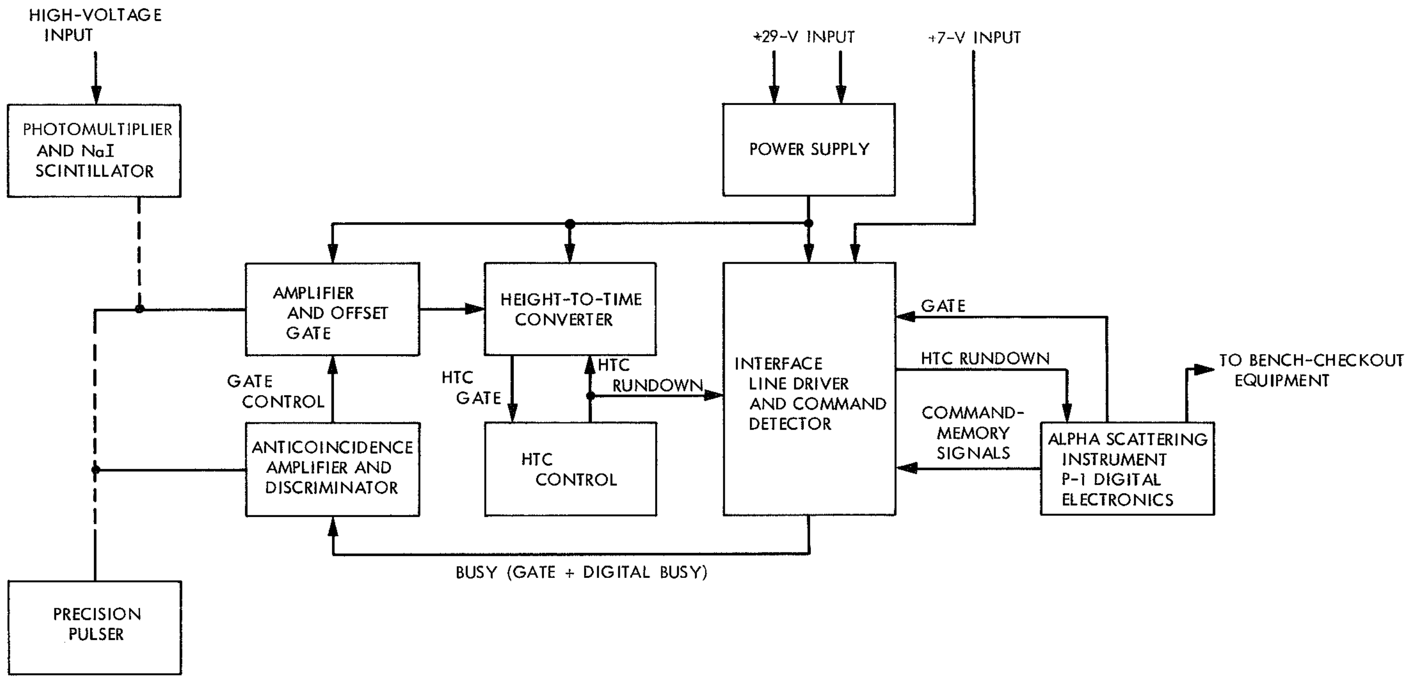

Fig. 2. Block diagram of breadboard test configuration

scattering instrument. The signals from the P-3A electronics were coupled to the P-1 alpha scattering digital electronics section using level shifters designed for these tests. The data from this system were read out with alpha scattering experiment bench-checkout equipment. A separate test was performed to verify the command sequence detection logic and control.

The system uses four of the P-3A modules to convert the charge pulse from the photomultiplier viewing the NaI(Tl) scintillator into a rundown signal whose width is proportional to the energy deposited in the scintillator, and to perform the anticoincidence function required to eliminate the response of NaI(Tl) to charged particles.

The amplifier and offset gate converts the photomultiplier signals into a current pulse, subtracts a fixed offset, and performs the linear gate function allowing only selected events into the height-to-time converter (HTC). The HTC and HTC control modules receive the current pulse and convert it into a voltage that is stored on a stretching capacitor. After a 1-μs delay to allow time for the anticoincidence gate to function, a constant current is switched on. The time required to discharge the stretching capacitor at this current determines the desired output signal. The anticoincidence amplifier and discriminator module will be connected to a second photomultiplier tube viewing a plastic scintillator charged-particle shield, and will produce a pulse whenever a signal from the plastic scintillator is detected. This signal prevents analysis of any signal detected by the HTC at the same time (within 1 μs).

The interface line driver converts the rundown signal from the HTC control into a level compatible with the P-1 digital electronics, and also converts the busy signal from the digital electronics into a level suitable for control of the linear gate in the amplifier and offset gate module by way of the anticoincidence module.

The output signal from the P-1 digital electronics was a word corresponding to the digitized energy of a detected event. These data were accumulated in the memory of a commercial pulse-height analyzer in the alpha scattering checkout equipment and printed out in conventional fashion.

Of the items shown in Fig. 2, the amplifier–offset gate, the anticoincidence amplifier and discriminator, the HTC and HTC control, and the power supply were part of the P-3A unit. The interface line driver and command detector were constructed for the test. Further discussion of the elements is given in the following section.

*1. **Alpha scattering instrument.*** The digital electronics of the P-1 alpha scattering instrument used in these tests were not modified in any way. The alpha scattering detector head was not required for these tests; instead of T-access as required for the dual-instrument configuration, the gamma ray detector was connected directly to the electronics. The additional transistor gating circuit was thus not simulated. This is not a notable limitation, because the interface as proposed is a straightforward digital function, and would not present any difficulty. The additional loading on the alpha scattering instrument signals caused by the presence of the gamma ray spectrometer, specifically the command-memory signal line and the HTC gate, would be negligible. The added load on the command-memory signal would be approximately 2 μA (2 MΩ), and the added load on the HTC gate would be 56 kΩ, plus, in both cases, whatever additional capacity is introduced by the spacecraft cabling.

*2. **Auxiliary electronics.*** The auxiliary electronics system and its power supply were only an approximate simulation of a flight instrumentation system.

a. Power supply. The P-3A second generation alpha scattering power supply was designed for a 3-W system, which resulted in its being inefficient in this lower power application. Also, the supply did not provide the 5 V necessary to operate the logic elements in the interface unit.

b. Height-to-time conversion. The HTC and the HTC control did not have the correct scale factor. Full scale was 255 μs, corresponding to 220 pulses of the alpha scattering digital electronics gated clock, instead of 127 pulses, the maximum channel address provided by the alpha scattering instrument. Because the HTC control is designed to produce a gated clock signal, and this function is provided by the alpha scattering digital electronics, some of the HTC control electronics were redundant.

c. Amplifier. The amplifiers used in this application were designed for measurements of low fluxes of charged particles with energies less than 7 MeV by means of silicon detectors. The output signal from the photomultiplier tube operating at normal voltages was several orders of magnitude larger than this value. A signal of 2×10^{-13} coulomb corresponded to channel 128. Decreasing the voltage to the photomultiplier tube was successful in bringing the signals within range, but noise (random noise from pickup, resistor noise, and leakage-current noise) became a problem under these conditions. The noise problem was so severe, in fact, that attempts to use a dual-scintillation detector system to test the anticoincidence system were unsuccessful. In addition, the existing system offset of 12 channels is larger than that desirable for a gamma ray experiment.

d. Reject system. The reject system used in the alpha scattering instrument was identical in concept to the anticoincidence shield method proposed for this experiment. A discriminator and the required reject logic provided pulse rejections in the same manner as would a flight instrument. Pulse timing and overlap were provided to assure that coincident pulses would prevent any output pulse in the alpha scattering instrument, and that, conversely, a reject pulse could not cause partial rejection of an analysis which had already begun. Reject operation was tested with pulses from a precision pulse generator that provided simultaneous input signals to both the signal and the reject amplifier, and verified that no output HTC pulse resulted.

*3. **Interface unit.*** The interface unit used in these tests was a breadboard design. Inexpensive integrated-circuit digital modules and less-than-optimum components were used instead of flight-quality items. The conversion of the flight interface to a unit of maximum performance is a straightforward engineering task.

*4. **Detector and detector power supply.*** The detector and the associated high voltage power supply used for the breadboard tests were nonruggedized laboratory units. The crystal size (2×2 in.) and shape were the same as those recommended for the flight assembly.

B. Performance

The following summarizes the performance obtained in tests of the breadboard system:

Resolution	For Cs^{137} (0.66 MeV), 8.8 to 9.2% (Fig. 3)
Live time	91% at 210 counts/s; 59% at 400 counts/s; The expected count rate will be on the order of 100 counts/s
Overload	Zero shift of 1.3 channels with 100 MeV pulses at a 60-pulse/s rate; negligible dead-time effect
Linearity	Integral linearity with pulser: $< 0.3\%$ Y^{88} peak ratio = 2.01 (Fig. 4)

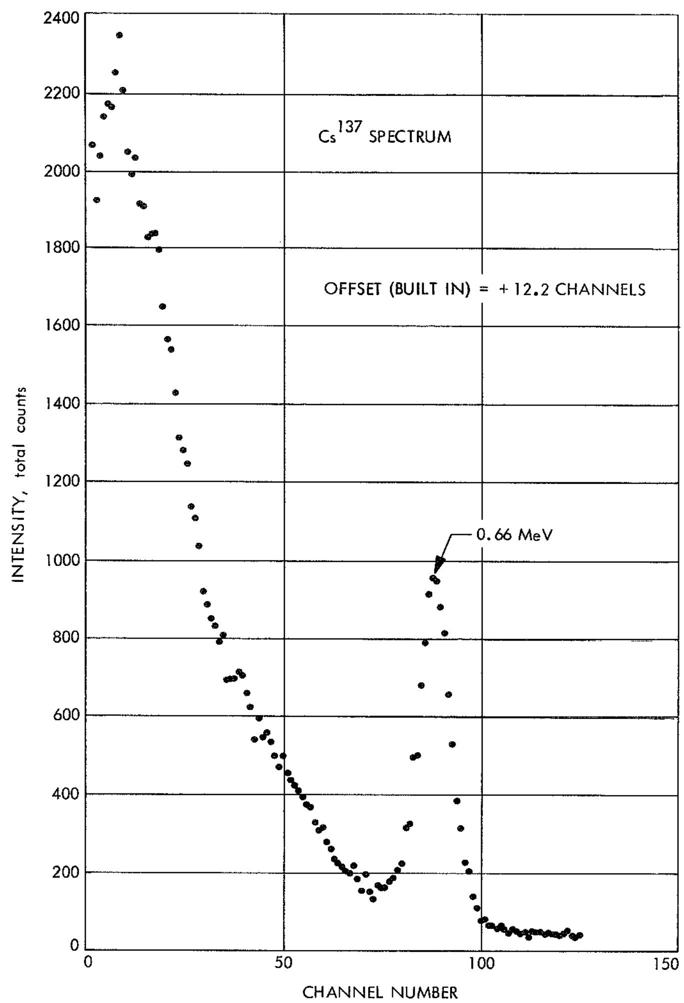

Fig. 3. Breadboard test: Cs^{137} spectrum

Pileup	Peak shift 0.5 channels at 2×10^4 counts/s (total Y^{88} spectrum)
Anticoincidence	Operation satisfactory with pulser inputs
Command sequence	Satisfactory operation

IV. Flight Instrument Description and Status of Development

This section describes a possible gamma ray flight instrument system based upon the requirements of Section III-A and the tests performed in Section III-B. The instrument consists of four major parts: (1) the detector assembly, containing the scintillation detector and photomultiplier tubes; (2) the auxiliary electronics system, containing the amplifiers, the height-to-time converter, the anticoincidence circuit, and the interface command circuits; (3) the power supplies for the photomultipliers and for the auxiliary electronics; and (4) the digital electronics of the alpha scattering instrument. The latter is common to the alpha scattering instrument. A block diagram of the gamma ray spectrometer system is shown in Fig. 5.

A. Detector Assembly

The detector assembly has been planned to consist of a 2 × 2-in. cylindrical NaI(Tl) scintillation crystal surrounded on all but one side by an anticoincidence shield. A schematic diagram of such an assembly is shown in Fig. 6. The anticoincidence shield would be a plastic scintillator optically decoupled from the NaI crystal. Charged particles have a high probability of interacting with the plastic scintillator, gamma rays a low probability of interacting. An output from the plastic scintillator will inhibit the analog-to-digital conversion of a simultaneous pulse from the NaI scintillator. If the flux of neutrons produced by cosmic ray particle cascades would make an appreciable contribution to the background by way of n-γ type of reactions in the NaI scintillator, the plastic scintillator will be loaded with, or surrounded with, a boron compound to reduce the effect. The NaI crystal would be doped with a small quantity of alpha particle emitting Am^{241} to provide a noninterfering calibration peak at about 4 MeV. A similar detector configuration has been designed and constructed for a satellite experiment. A scaled-down model is proposed here.

B. Auxiliary Electronics

The electronics system converts the charge signal from the gamma ray detector into a variable-width pulse for processing in the digital electronics assembly, rejects gamma ray detector signals coincident with pulses from the plastic scintillator shield, and detects the command sequence. The latter enables the system to apply high voltage to the detector and to transmit data to the alpha scattering digital electronics.

The system consists of three elements: (1) the gamma ray scintillator signal amplifier, gate, and HTC system, (2) the plastic scintillator signal amplifier and discriminator, and (3) the command interface system. Improved versions of the first two items were designed subsequent to this study as a breadboard of a proposed orbiting gamma ray spectrometer (Ref. 6).

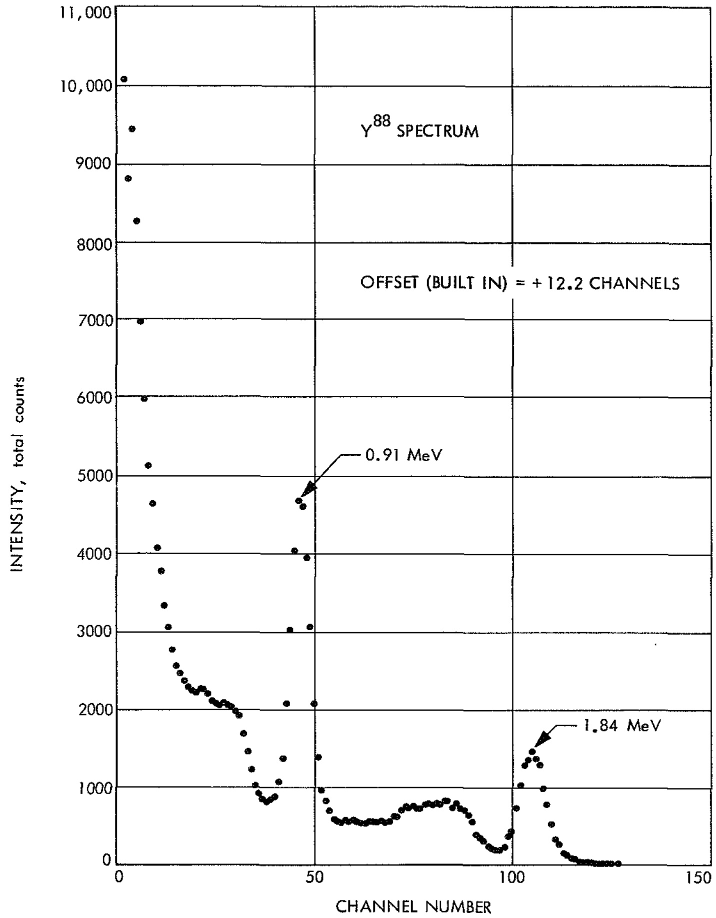

Fig. 4. Breadboard test: Y^{88} spectrum with 100 MeV equivalent overload pulses at 60 pulses/s

1. Gamma ray signal chain. These circuits convert the charge pulse from the photomultiplier viewing the NaI gamma ray detector into a variable-width signal called *rundown,* which is subsequently digitized using circuits already present in the alpha scattering instrument.

The charge-sensitive amplifier converts the photomultiplier output into a smoothly varying voltage pulse that is, in turn, converted into a current signal. After an offset is subtracted, the signal is then passed through a linear gate. Such operation using current-mode signals provides a stable, linear offset and unambiguous gate operation.

The HTC system has required only minor changes from that designed for the second generation alpha scattering project. These changes concern the different scale factor required for a 120-μs full-scale signal and the omission of a gated clock from the system. The HTC is made by means of the Wilkinson capacitor-rundown technique. The input signal is used to charge a stretching capacitor to a voltage corresponding to the peak value of the input signal (Fig. 5). Just after the peak occurs, an HTC gate signal is generated. This signal is delayed about 1 μs to provide time for rejection by the anticoincidence system to occur, and then generates a rundown signal that switches on a constant-current source to discharge the capacitor. When the stretching capacitor is discharged, the HTC gate signal disappears, promptly turning off the rundown signal. The rundown signal is thus the desired pulse-width signal to be digitized by the digital electronics assembly. An anticoincidence pulse arriving in the 1 μs between HTC gate and rundown overrides the rundown signal and quickly discharges the capacitor. The 1-μs delay provides timing margins to assure that the reject signal will always inhibit the HTC signal before the rundown signal, and consequently the output signal, are produced.

2. Reject system. The reject system makes use of the fact that the great majority of charged particles that

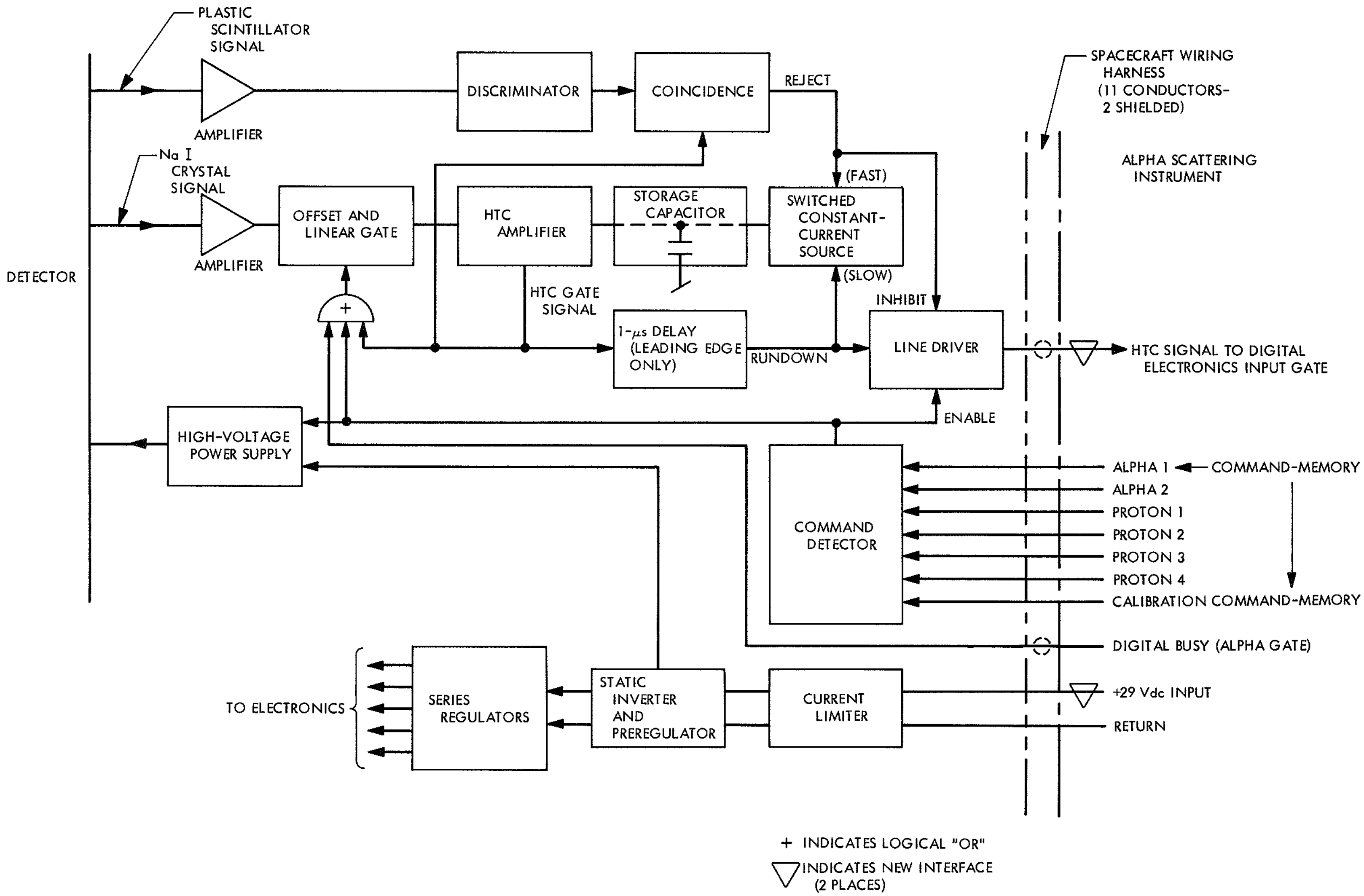

Fig. 5. Block diagram of proposed gamma ray spectrometer

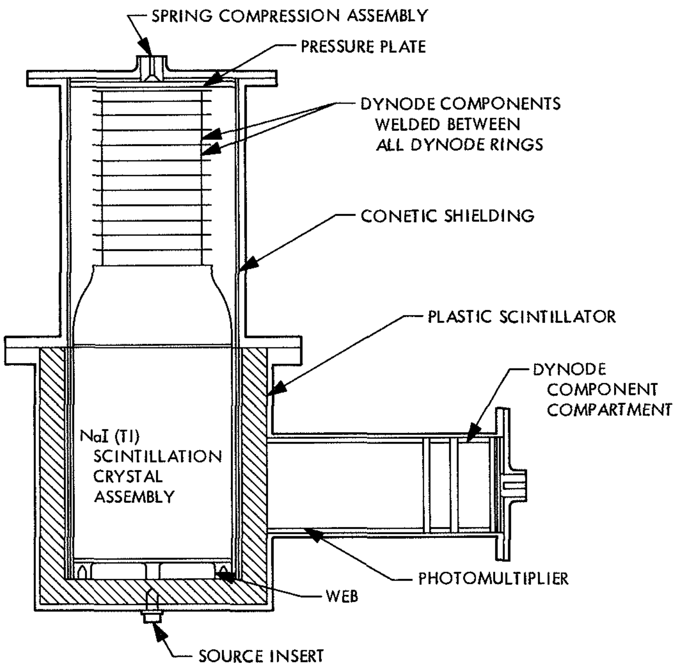

Fig. 6. Schematic diagram of gamma ray detector

interact with the inorganic scintillator will have traversed the plastic scintillator and will, therefore, generate simultaneous pulses in both signal channels. This coincidence is detected and used to form a veto signal. The reject signal then closes the linear gate in the pulse-height-analysis channel, discharges the capacitor in the HTC, and inhibits the output line driver. Any possibility of race conditions occurring is eliminated by choosing the shaping time constant for the plastic system to be 0.5 μs, and that of the NaI system to be 1 μs. A timing diagram of the system is shown in Fig. 7.

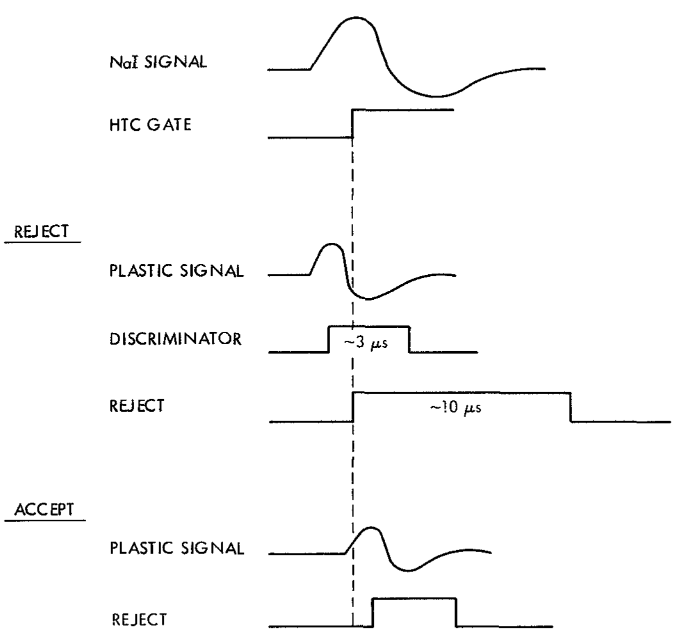

Fig. 7. Diagram of reject system timing

3. Command interface. The command interface section will be assembled using integrated-circuit logic elements to provide the command sequence detection function to enable instrument operation. In the proposed design, as shown in Fig. 8, the gamma ray spectrometer will only be enabled when all seven alpha scattering instrument command-memory signals are in the high (detector *off*) state, and the A binary is reset. The A binary will be set in the event that the sequence of commands leading from the *all-on* state (which resets A) to the *all-off* state (necessary for operation of the gamma ray system) is other than that prescribed. A sequence of commands leading to enabling of the gamma ray system is as follows (α and P refer to the alpha and proton detectors, respectively, and C to the calibration pulser, all in the alpha scattering detector head):

Step	Command status							Comment
0	α_1	α_2	P_1	P_2	P_3	P_4	C	Resets A
1	α_1	α_2	P_1	P_2	P_3	P_4	$\overline{C}$	
2	$\overline{\alpha_1}$	$\overline{\alpha_2}$	P_1	P_2	P_3	P_4	$\overline{C}$	
3	$\overline{\alpha_1}$	$\overline{\alpha_2}$	$\overline{P_1}$	$\overline{P_2}$	P_3	P_4	$\overline{C}$	
4	$\overline{\alpha_1}$	$\overline{\alpha_2}$	$\overline{P_1}$	$\overline{P_2}$	$\overline{P_3}$	$\overline{P_4}$	$\overline{C}$	Gamma ray *on*
5	$\overline{\alpha_1}$	$\overline{\alpha_2}$	$\overline{P_1}$	$\overline{P_2}$	$\overline{P_3}$	$\overline{P_4}$	$\overline{C}$	Gamma ray *off*, Sets A
6	$\overline{\alpha_1}$	$\overline{\alpha_2}$	$\overline{P_1}$	$\overline{P_2}$	$\overline{P_3}$	$\overline{P_4}$	$\overline{C}$	Gamma ray *off*, A remains set

Note that each step requires one spacecraft command, and also note that the wrong-sequence step 5 disables the gamma ray detector. If this should occur, then a repetition of steps 0 through 4 would be necessary to return the detector to the *on* state. This technique gives essentially unlimited command flexibility to the alpha scattering experiment because both step 0, required to reset A, and step 4, required to enable the gamma ray instrument, are normal operating configurations.

C. Power Supplies

Two types of power supplies are required for the gamma ray instrument. Regulated low voltage supplies are required for operation of the auxiliary electronics.

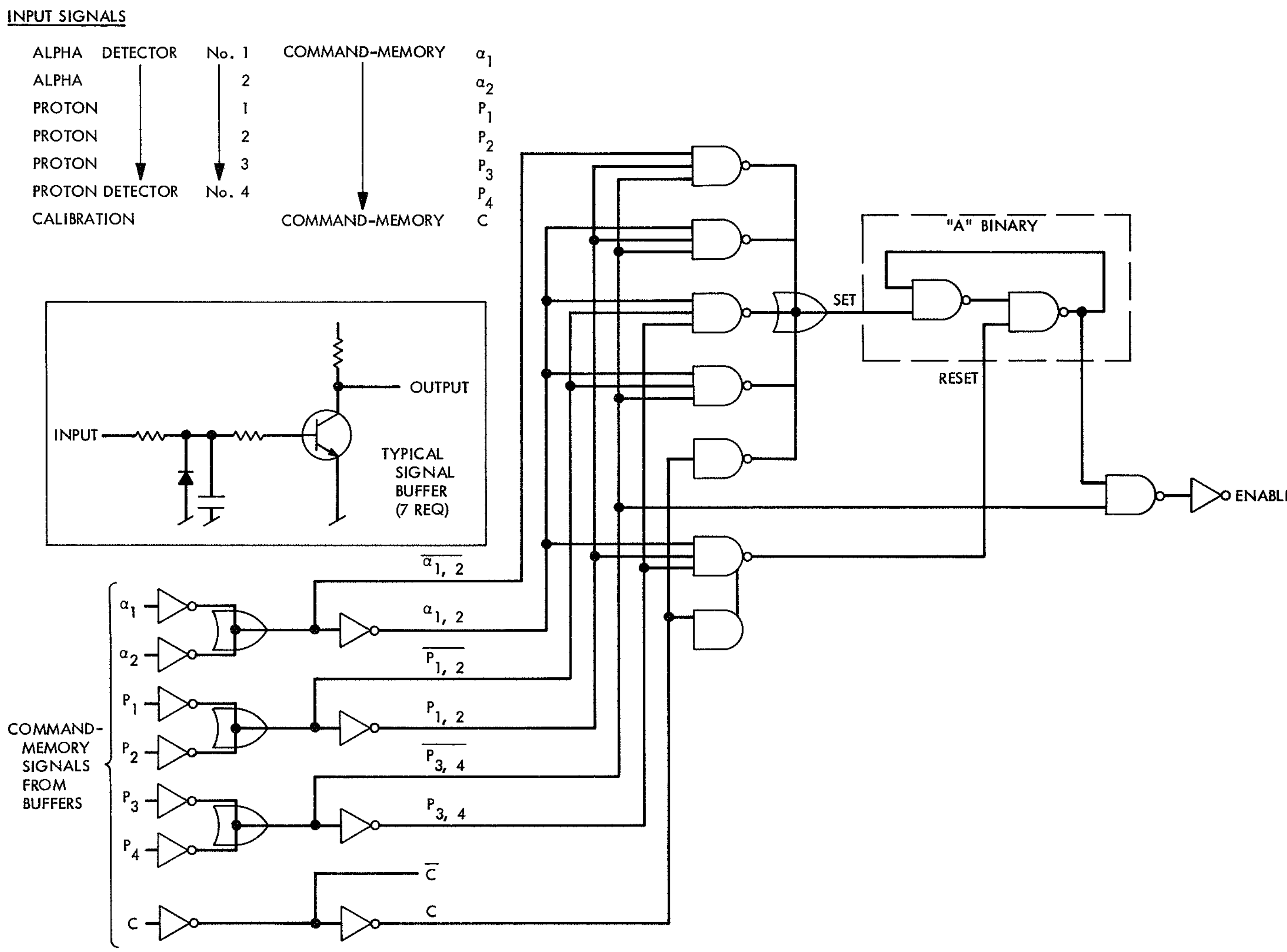

Fig. 8. Logic diagram of command sequence detector

Well regulated high voltage supplies are necessary for the photomultipliers. To enhance system reliability and decrease the power requirement, it would be desirable for the command enable signal to also turn on the high voltage supply. Protection against faults in the low voltage supply would be provided by current-limiting.

Although not described here, a system could be used that would provide separate supplies for the command detector and for the remainder of the electronics. Only the first supply would be operating unless the enabling command was present.

1. Low voltage power supply. A boost-regulated, two-core static inverter and series regulators would be used for the power supply. This technique provides the following advantages:

(1) Return-isolation, to avoid system ground loops and noise.

(2) Efficient power conversion, and independence from power source variations.

(3) Highly stable output voltage regulation.

System protection would be provided by an input current-limiter, adequately designed and packaged to withstand continuous full-load operation. In the event of failure in the auxiliary detector, operation of the alpha scattering instrument would be unaffected.

2. High voltage power supply. A high voltage power supply (100 to 1500 Vdc) is required to operate the photomultiplier tubes. At the time of this study, Jet Propulsion Laboratory had made two flight-hardened designs available. Since that time, another high voltage supply with a gain change command capability has been built and tested as part of a gamma ray spectrometer breadboard and prototype (Ref. 6).

D. Digital Electronics

The function of the alpha scattering instrument digital electronics has been discussed earlier. It provides the gated clock used to digitize the pulse-width signal derived from the HTC rundown signal described in Section IV-A-1, and provides temporary storage for this digital information. The digital information is subsequently entered into the spacecraft telemetry system.

Data processing is identical to that used by the existing instrument. In addition to data processing, the digital electronics provides command-memory functions, a series of seven bistable elements controlled by spacecraft pulse commands. The interface between the digital electronics and the added gamma ray spectrometer is shown in Fig. 9. This interface design would assure that only the most unlikely set of failures would result in interference with the alpha scattering experiment. All T-connection signals are isolated with resistors large enough to avoid any loading even if the associated semiconductors were to fail. Dual redundancy is provided in the HTC signal interface since the command enable signal will be required for the line driver to operate, in addition to the logic gating shown in Fig. 8.

E. System Parameters

This section outlines the design and performance specifications for the gamma ray part of the combined instrument.

Interface requirements

Power

Spacecraft power when operating, 600 mW of +29 V; 400 mW at standby (could be reduced to 50 mW with some increase in complexity)

Weight

Electronics	800 g
Detector	1500 g
Cabling	500 g
	2800 g

Telemetry

Existing 2200 bits/s alpha scattering instrument data channel can be used

Command

Existing alpha scattering commands can be used

Viewing requirements

Detector must have unobstructed view of lunar surface; orientation and height above surface are not critical

Thermal environment

Electronics	−40° to +100°C
Detector	−40° to + 80°C

The upper limit for the detector could be extended if necessary by going to a high temperature plastic scintillator; it is desirable to confine the change in temperature during operation of the instrument to 20°C or less

Time of operation

4 h or longer is desired

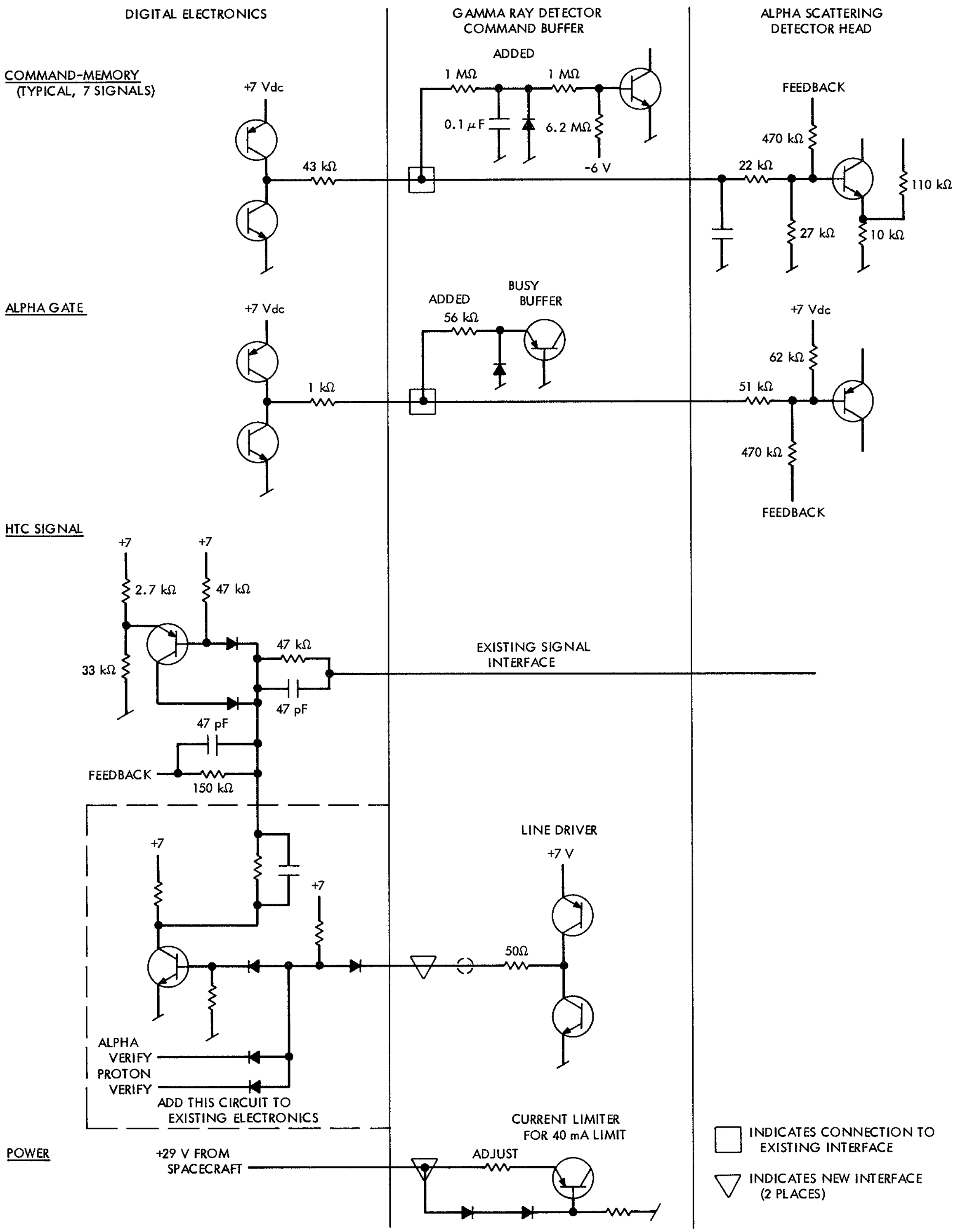

Fig. 9. Schematic diagram of gamma ray–alpha scattering interface

Performance

Radiation detected

0.2 to 5 MeV gamma rays

Detector

NaI scintillation crystal 2 × 2-in. cylinder, with plastic scintillator charged-particle rejection

Resolution

9.0% or better at 0.66 MeV

Signal output

Variable-width pulse 0 ±0.2-V low state, + 7 ±0.7-V high state, 50-Ω source, rise and fall times 100 ns; pulse width t_w given by $t_w = K(E - E_{offset})$ $t_w \leq 150$ μs maximum

Signal input

(1) HTC gate signal from digital electronics; load resistance > 1 MΩ

(2) Command-memory signals (7) from digital electronics; load resistance > 1 MΩ

Operating sequence

Operation as permitted by alpha scattering experiment requirements. Operating enabled by the following command sequence:

(1) α_1 *on*
(2) α_2 *on*
(3) P_1 *on*
(4) P_2 *on*
(5) P_3 *on*
(6) P_4 *on*
(7) Calibrate *on*
(8) Calibrate *off*
(9) α_1 or α_2 *off*
(10) P_1 and P_2 *off*
(11) P_3 and P_4 *off*

Instrument operation will stop upon the turn-on of any alpha scattering detector.

Weight and power summary

	Weight	Power*
Detector components	1200 g	100 mW
Detector structure	300 g	
Electronics	675 g	600 mW
Electronics structure	125 g	
Cabling	500 g	
Total	2800 g	700 mW

*at 75% efficiency

V. Conclusions

The successful operation of a gamma ray spectrometer using a digital system specifically designed for the *Surveyor* alpha scattering experiment with a minimum of modifications to that system demonstrates the instrumental commonality of these two techniques, and the feasibility of a combined system where the circumstances warrant. In this study the supplemental role of the gamma ray spectrometer dictated the need to compromise in such areas as detector size (i.e., efficiency) and operational sequence. This need not be a limitation in future applications.

The alpha scattering experiment requires 4 to 24 h to accumulate sufficient counts for adequate-to-excellent statistics and will therefore be used on missions where relatively long periods of immobile operation are possible. For good counting statistics, a gamma ray spectrometer will require about 0.5 to 1 h for each area sampled. The difficulty of obtaining sufficient bandwidth and operational time when each count is read out directly to telemetry points up the advantage of including a core memory system of the type now under development for space experiments. With adequate memory storage the duty cycle can approach unity.

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